ESA Climate Change Initiative – Fire_cci
O3.D4 Product Validation Report – Small Fire Database - South America

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Author	Mihai A. Tanase, Ángel Fernández Carrillo, Miguel Ángel Belenguer Plomer, Joshua Lizundia-Loiola
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Project Partners

Prime Contractor/ Scientific Lead & Project Management	UAH – University of Alcala (Spain)
Earth Observation Team	UAH – University of Alcala (Spain)
System Engineering	DINSA – Desarrollo Informático S.A. (Spain)

Distribution

Affiliation	Name	Address	Copies
ESA	Stephen Plummer (ESA)	stephen.plummer@esa.int	electronic copy
Project Team	Emilio Chuvieco (UAH) M. Lucrecia Pettinari (UAH) Joshua Lizundia (UAH) Gonzalo Otón (UAH) Mihai A. Tanase (UAH) Miguel Ángel Belenguer (UAH)	emilio.chuvieco@uah.es mlucrecia.pettinari@uah.es joshua.lizundia@uah.es gonzalo.oton@uah.es mihai.tanase@uah.es miguel.belenguer@uah.es	electronic copy

Summary

The aim of Option 3 is providing Sentinel-1 burned area products over a large demonstrator area (LDA) located in tropical South America. This document supplements the deliverables *O3.D1 Algorithm Theoretical Basis Document (ATBD) – Small Fires Database (SFD) for the large demonstrator area (LDA) in South America* and *O3.D2. Burned area database for candidate validation tiles* that describe the BA algorithm and respectively, the validation framework. The document describes the results of the product validation activity.

	Affiliation/Function	Name	Date
Prepared	UAH	Mihai A. Tanase	25/02/2019
Reviewed	UAH – Project Manager	Lucrecia Pettinari	28/02/2019
Authorized	UAH - Science Leader	Emilio Chuvieco	28/02/2019
Accepted	ESA - Technical Officer	Stephen Plummer	

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1 Executive Summary

Burned area (BA), as derived from satellites, is considered the primary variable that requires climate-standard continuity. It can be combined with information on burn efficiency and available fuel load to estimate emissions of trace gases and aerosols. Measurements of BA may be used as direct input (driver) to climate and carbon cycle models or, when long time series of data are available, to parameterize climate-driven models for BA (GCOS, 2016). The aim of Option 3 is to provide Sentinel-1 burned area products over a large demonstrator area (LDA) located in tropical South America. As such, Option 3 extends the areas mapped within the “Small fire database” to tropical regions in South America.

Since climate and carbon cycle modeling need information on the validity of the input BA products, the Product Validation Report PVR (this document), describes the approaches and methods used to assess the quality of BA products obtained from the Sentinel-1 algorithm in tropical South America. The product validation over Amazon LDA follows the principles outlined in the main Fire_cci proposal (see Padilla et al. 2018) with changes accommodating the specific conditions encountered for Option 3: i) reduced temporal frequency of the generated BA products (year 2017), ii) reduced availability of cloud free optical imagery (used to derive the reference dataset), and, iii) reduced number of biomes (i.e., tropical forest and tropical and subtropical savanna).

Since large scale ground assessment of BA products is cost prohibitive the reference dataset (i.e., validation database) was developed using medium resolution optical images, acquired close enough in time as to portray the same ground conditions as the input Sentinel-1 images from which the BA product is generated. The main optical sensors used to derive the reference BA were Landsat 8 and Sentinel 2. The Landsat sensors were given preference to preserve compatibility with the validation datasets developed within the Fire_cci project. For a sample of 46 validation sites, reference fire perimeters were generated for the year 2017. CEOS LPV (land product validation) protocols were used to generate the reference data and peer-reviewed methods were used to summarize and express the validation results as described in detail in *O3.D2. Burned area database for candidate validation tiles* (Tanase and Fernández Carrillo 2018). The reference BA dataset was specifically designed for the SFD Amazon product to ensure temporal overlaps with Sentinel-1 derived BA estimates.

The Sentinel-1 based product showed a commission error (CE) of 37% and an omission error (OE) of 52% for the burned area class. The Dice Coefficient (DC) was 54%. By strata, the most accurate results were obtained for *Grasslands high burn* (DC = 56%). For the remaining classes DC values ranged between 30-52%. Accuracy metrics varied greatly at tile level (0 to 100%) largely due to the small number of burned area observed for tiles with extreme values.

2 Introduction

2.1 Purpose of the document

The objective of the Product Validation Report is to describe the validation results for the BA derived within Fire_cci Option 3 from Sentinel-1 data over tropical South America. The document supplements existing PVRs and follows the validation framework described in Tanase and Fernández Carrillo (2018).

2.2 Background

Within Fire_cci Phase 2, the BA products are validated using reference data collected by means of probabilistic sampling carried out both in space and time. In addition, the sampling allocation follows stratification criteria to properly allocate samples to each stratum and optimize resources dedicated to reference data generation (Padilla et al. 2017). Such complex validation designs recognize the shortcomings of earlier methods based on using a relatively reduced number of locations to validate global BA products (Chuvieco et al. 2008; Roy and Boschetti 2009; Roy et al. 2008; Tansey et al. 2008).

As per the baseline project validation strategy, a stratified random sampling design was used to provide reference BA estimates and infer the accuracy of the BA product produced within Option 3 (Tanase and Fernández Carrillo 2018). The sampling units were the Thiessen Scene Areas (TSAs) defined by the Landsat World Reference System II (WRS-II). The total number of samples (46) was computed according to Olofsson et al. 2014 under the following assumptions: i) proportion of disturbed area 20% (i.e., TSA with high fire activity), ii) expected user accuracy for burned areas, 60% (Padilla et al. 2014a; Padilla et al. 2014b), iii) expected user accuracy for not affected areas, 90%, and iv) expected standard error for the overall accuracy, 5% (Tanase and Fernández Carrillo 2018). The sampling units were stratified to ensure sufficient sampling over major Olson ecoregions (Olson et al. 2001) with a focus on regions with high fire activity (Figure 1).

Samples were allocated by strata proportionally with the square root of the burned area in each class (Padilla et al. 2017). The 46 validation TSAs were split as follows: Forest high burn (14), Forest low burn (13), Grasslands/Shrublands high burn (6), and Grasslands/Shrublands low burn (13). TSAs were drawn randomly from the entire population after eliminating the three TSAs used during the BA algorithm development (Tanase and Fernández Carrillo 2018).

A semi-automatic procedure was used to generate the reference fire perimeters for a core region (30 km by 20 km) in each sample. A semi-automatic BA classification based on Random Forests classifiers trained with data selected by a skilled operator was used. The classification consisted in repetitive iterations of visual inspection, delineation of training polygons and classification until no further errors could be perceived on the visual inspection.

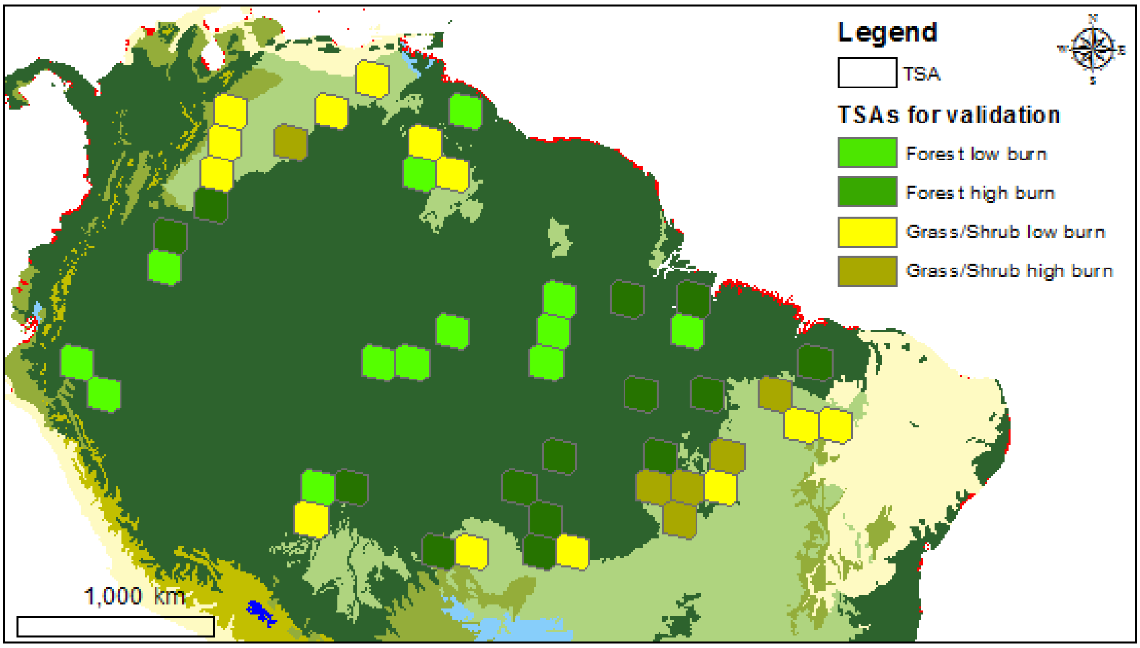

Figure 1: Sampling units selected for validation (by biome and fire activity).

Since the BA product over Amazon LDA was generated for one year only (2017) validation of temporal trends was not needed which simplified the validation approach adopted for Option 3 products (Tanase and Fernández Carrillo 2018).

Accuracy estimates were based on the cross-tabulation approach (Latifovic and Olthof 2004) by accounting for the spatio-temporal coincidences and disagreements on estimates of location and timing of burns between a reference map and the target map. This approach is widely used (Boschetti et al. 2004; Boschetti et al. 2016; Chuvieco et al. 2008; Giglio et al. 2009; Padilla et al. 2017; Padilla et al. 2014a; Padilla et al. 2015; Padilla et al. 2014b; Roy and Boschetti 2009). The result of cross tabulation was represented as an error matrix which expresses the amount of agreement and disagreement between product and reference classifications. Apart from the common ratios between combinations of error matrix cells (i.e., commission and omission errors) the Dice Coefficient (DC) was used since it summarizes both commission and omission errors of the category 'burned' (Padilla et al. 2015).

Since the reference data set may include areas burned during several time periods (i.e. the reference fire perimeters were generated from consecutive series of image pairs) the product validation was carried out for the entire period with the binary maps defined by the first and last acquisition dates of the optical images. When temporal gaps over 32 days were present in the optical time series, the validation was carried out by intervals with the binary maps being defined by the acquisition dates of the image pairs included in each individual interval.

Since the Amazon LDA product covered a much smaller area (i.e. homogenous) when compared to global products, the size of the reference BA relative to the product coverage was relatively high, the validation temporal dimension spans only one year, and only two strata (biomes) are present, the global estimate of accuracy is computed without considering a stratified sampling design as in the case of the global product.

3 Results

The area covered by the validation samples reached about 10 Mpixels (Table 1), or approximately 1.5 Mha which amounts to 0.2% of the total area mapped (720 Mha) within the Option 3. About 11% of the reference pixels were burned. By biome, the validation samples were divided 54% to 46% between forests and grasslands respectively [D2] with the lowest proportion being allocated to *Grasslands high burn* (16% of the sampled area). For the validation sample, when considering all classes, CE and OE were balanced (36-37%) with a DC of 63% (Table 1). By class, the most accurate results (DC=74%) were obtained for Grasslands high burn (Table 2). For the remaining classes DC values were rather similar (40-50%). Accuracy metrics varied greatly by tile (0 to 100%) due to the small BA observed over some tiles which resulted in extreme values (Annex 2). On average, the effective validation area at TSA level (i.e. not masked due to cloud presence or Landsat 7 scan line errors) was 35,000 ha which amount to about 60% of the sampled.

The accuracy metrics for the **BA product** was computed using the proportions of estimated area as per Olofsson et al. (2014). The DC for the BA class was 54% (Table 3). At product level, CE and OE for burned areas varied between 0.11 and 0.65 with the most accurate results (DC=56%) being obtained for *Grasslands high burn*. For the remaining classes DC values were similar, hovering around 50% except for the class *Grasslands low burn*. The total BA in the Amazon LDA for year 2017 was estimated at 589,479±1026 km^2.

Table 1. Confusion matrix for the pooled validation samples

	Reference					
Detected	Unburned	Burned	Total	CE	OE	DC
Unburned	8198814	394130	8610682	0.05	0.05	0.95
Burned	411868	690792	1084922	0.37	0.36	0.63
Total	8592944	1102660	9695604			

Table 2. Confusion matrix for the pooled validation samples stratified by biome and fire activity

	Pixel counts / Reference					
		Forest		Grasslands		
Detected	Unburned	High burn	Low Burn	High burn	Low Burn	Total
Unburned	8198814	27396	4104	225004	137626	8592944
Forest HB	143847	99282				243129
Forest LB	31393		16986			48379
Grass HB	104388			476703		581091
Grass LB	132240				97821	230061
Total	8610682	126678	21090	701707	235447	9695604

	Accuracy metrics				
	Forest			Grasslands	
	Unburned	High burn	Low Burn	High burn	Low Burn
OE	0.05	0.59	0.65	0.18	0.57
CE	0.05	0.22	0.19	0.32	0.58
DC	0.95	0.54	0.49	0.74	0.42

Table 3. Accuracy assessment estimates by strata and when pooling all strata. The estimates were computed using an error matrix populated by estimated proportions of area as described in Oloffson et al. (2014)

	Class	BA (km^2)	CE	OE	DC
Stratified by biome and fire activity	Forest high burn	76,975 ± 367	0.59	0.28	0.52
	Forest low burn	30,215 ±342	0.65	0.11	0.50
	Grasslands high burn	307,207 ±737	0.18	0.57	0.56
	Grasslands low burn	139,995 ±586	0.57	0.77	0.30
All strata	burned	589,479 ±1026	0.37	0.52	0.54
	unburned	6,598,541 ±1026	0.05	0.03	0.96

4 References

Boschetti, L., Flasse, S.p.P., & Brivio, P.A. (2004). Analysis of the conflict between omission and commission in low spatial resolution dichotomic thematic products: The Pareto Boundary. Remote Sensing of Environment, 91, 280-292

Boschetti, L., Stehman, S.V., & Roy, D.P. (2016). A stratified random sampling design in space and time for regional to global scale burned area product validation. Remote Sensing of Environment, 186, 465-478

Chuvieco, E., Opazo, S., Sione, W., Del Valle, H., Anaya, J., Di Bella, C., Cruz, I., Manzo, L., López, G., Mari, N., González-Alonso, F., Morelli, F., Setzer, A., Csiszar, I., Kanpandegi, J.A., Bastarrika, A., & Libonati, R. (2008). Global Burned Land Estimation in Latin America using MODIS Composite Data. Ecological Applications, 18, 64-79

GCOS, 2016. The Global Observing System for Climate: Implementation Needs (GCOS-200). Available online at https://library.wmo.int/opac/doc_num.php?explnum_id=3417; last accessed 04/11/2017.

Giglio, L., Loboda, T., Roy, D.P., Quayle, B., & Justice, C.O. (2009). An active-fire based burned area mapping algorithm for the MODIS sensor. Remote Sensing of Environment, 113, 408-420

Latifovic, R., & Olthof, I. (2004). Accuracy assessment using sub-pixel fractional error matrices of global land cover products derived from satellite data. Remote Sensing of Environment, 90, 153-165

Olofsson, P., Foody, G.M., Herold, M., Stehman, S.V., Woodcock, C.E., & Wulder, M.A. (2014). Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment, 148, 42 - 57

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'Amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P., & Kassem, K.R. (2001). Terrestrial ecoregions of the world: a new map of life on Earth. Biogeosceinces, 51, 933-938

Padilla, M., Olofsson, P., Stephen V., S., Tansey, K., & Chuvieco, E. (2017). Stratification and sample allocation for reference burned area data. Remote Sensing of Environment, in press

Padilla, M., Stehman, S.V., & Chuvieco, E. (2014a). Validation of the 2008 MODIS-MCD45 global burned area product using stratified random sampling. Remote Sensing of Environment, 144, 187-196

Padilla, M., Stehman, S.V., Hantson, S., Oliva, P., Alonso-Canas, I., Bradley, A., Tansey, K., Mota, B., Pereira, J.M., & Chuvieco, E. (2015). Comparing the Accuracies of Remote

Sensing Global Burned Area Products using Stratified Random Sampling and Estimation. Remote Sensing of Environment, 160, 114-121

Padilla, M., Stehman, S.V., Litago, J., & Chuvieco, E. (2014b). Assessing the temporal stability of the accuracy of a time series of burned area products. Remote Sensing, 6, 2050-2068

Padilla M., Wheeler J., Tansey K. (2018) ESA CCI Fire Disturbance: D4.1.1. Product Validation Report, version 2.1. Available at: https://www.esa-fire-cci.org/documents

Roy, D.P., & Boschetti, L. (2009). Southern Africa validation of the MODIS, L3JRC, and GlobCarbon burned-area products. IEEE Transactions on Geoscience and Remote Sensing, 47, 1032-1044

Roy, D.P., Boschetti, L., Justice, C.O., & Ju, J. (2008). The collection 5 MODIS burned area product—Global evaluation by comparison with the MODIS active fire product. Remote Sensing of Environment, 112, 3690-3707

Tanase M.A., Fernández Carrillo A. (2018) ESA CCI ECV Fire Disturbance: O3.D2 Burned Area database for candidate validation tiles, version 1.1. Available at: https://www.esa-fire-cci.org/documents

Tansey, K., Gr\'e, g., Jean-Marie, Defourny, P., Leigh, R., Pekel, J.-F.c., ,ois, van Bogaert, E., & Bartholom\'e, Etienne (2008). A new, global, multi-annual (2000--2007) burnt area product at 1 km resolution. Geophysical Research Letters, 35

Annex 1: Acronyms and abbreviations

ATBD	Algorithm Theoretical Basis Document
BA	Burned Area
CCI	Climate Change Initiative
CE	Commission Error
CEOS	Committee on Earth Observation Satellites
DC	Dice Coefficient
ESA	European Space Agency
ECV	Essential Climate Variables
GCOS	Global Climate Observing System
LDA	Large Demonstrator Area
LPV	Land Product Validation Subgroup of CEOS
OE	Omission Error
PVR	Product Validation Report
SAR	Synthetic Aperture Radar
TSA	Thiessen Scene Area
WRS	World Reference System

Annex 2: Accuracy estimates for individual samples (TSA level)

TSA	Validation period	Detection period	Effective validation area (ha)[1]	Reference burned area (ha)[2]	OA	OE	CE	DC	relB
001/067	2017.06.17 - 2017.09.29	2017.06.19 - 2017.09.29	33680	83	0.99	0.52	0.85	0.23	2.26
001/068	2017.04.14 - 2017.10.07	2017.04.14 - 2017.10.05	3444	0.6	0.93	0.00	1.00	0.01	365.25
002/054	2016.12.14 - 2017.01.15	2016.12.21 - 2017.01.14	26729	569	0.98	0.93	0.17	0.13	-0.92
003/055	2017.08.18 - 2017.09.19	2017.08.22 - 2017.09.15	11558	50	1.00	1.00	0	0.00	-1.00
004/056	2016.12.28 - 2017.04.03	2016.12.18 - 2017.04.05	59629	23930	0.66	0.80	0.16	0.32	-0.76
006/055	2017.01.03 - 2017.02.28	2017.01.04 - 2017.03.05	30854	91	1.00	1.00	1.00	0.00	-0.35
006/056	2017.01.03 - 2017.03.16	2017.01.04 - 2017.03.05	38974	1017	0.96	0.99	0.97	0.02	-0.62
006/057	2017.01.03 - 2017.03.16	2017.01.04 - 2017.03.05	34380	6536	0.83	0.87	0.25	0.22	-0.83
006/058	2017.01.11 - 2017.03.16	2017.01.09 - 2017.03.22	25613	1426	0.93	0.53	0.63	0.42	0.26
007/059	2017.01.10 - 2017.02.19	2017.01.14 - 2017.03.03	52777	0	1.00	0	0	1	N/A
007/060	2017.01.18 - 2017.02.19	2017.01.14 - 2017.02.07	54742	0	1.00	0	0	1	N/A
008/064	2017.09.01 - 2017.10.06	2017.09.06 - 2017.09.30	42594	19	0.99	0.86	0.99	0.02	15.49
009/063	2017.06.06 - 2017.09.21	2017.06.07 - 2017.09.23	14860	0	1.00	0	0	1	N/A
219/065	2017.05.07 - 2017.10.22	2017.05.14 - 2017.10.29	50971	4321	0.86	0.40	0.67	0.43	0.82
220/063	2017.05.14 - 2017.10.29	2017.05.19 - 2017.11.03	32777	4351	0.93	0.32	0.25	0.71	-0.08
220/065	2017.06.07 - 2017.10.29	2017.06.12 - 2017.11.03	46245	17085	0.69	0.47	0.41	0.55	-0.11
221/064	2017.06.06 - 2017.10.04	2017.06.05 - 2017.10.03	35402	28217	0.83	0.16	0.06	0.89	-0.10
222/066	2017.04.26 - 2017.10.19	2017.04.23 - 2017.10.20	40089	13523	0.76	0.47	0.32	0.60	-0.22
222/067	2017.05.04 - 2017.10.19	2017.05.05 - 2017.10.20	55027	4582	0.88	0.46	0.66	0.42	0.58
223/064	2017.06.20 - 2017.09.16	2017.06.22 - 2017.09.14	11928	77	0.98	0.45	0.81	0.28	1.84
223/067	2017.03.16 - 2017.10.10	2017.03.18 - 2017.10.08	47721	7026	0.88	0.26	0.43	0.65	0.30
223/068	2017.03.16 - 2017.10.26	2017.03.18 - 2017.10.20	57198	37484	0.83	0.09	0.16	0.87	0.08
224/061	2017.06.03 - 2017.07.05	2017.06.03 - 2017.07.09	56117	105	1.00	0.42	0.15	0.69	-0.32
224/062	2017.06.03 - 2017.09.07	2017.06.03 - 2017.09.07	25716	118	0.99	0.81	0.72	0.23	-0.32
224/066	2017.04.08 - 2017.10.25	2017.04.04 - 2017.10.13	45324	10633	0.74	0.13	0.53	0.61	0.85
224/067	2017.04.08 - 2017.09.23	2017.04.04 - 2017.09.19	42051	2093	0.97	0.37	0.30	0.66	-0.09
225/064	2017.06.10 - 2017.09.14	2017.06.08 - 2017.09.12	29584	1065	0.93	0.15	0.68	0.46	1.66
226/061	2017.07.11 - 2017.10.23	2017.07.19 - 2017.10.23	4914	47	0.99	0.90	0.66	0.16	-0.70
226/069	2017.05.08 - 2017.09.13	2017.05.08 - 2017.09.17	69772	436	0.97	0.29	0.86	0.23	4.09
227/066	2017.05.07 - 2017.09.12	2017.05.08 - 2017.09.17	37702	0	1.00	0	1.00	0.00	N/A
227/068	2017.05.07 - 2017.10.14	2017.05.13 - 2017.10.16	36345	132	0.96	0.08	0.92	0.15	10.17
227/069	2017.05.07 - 2017.10.06	2017.05.13 - 2017.10.04	33049	93	0.98	0.38	0.89	0.19	4.57
228/061	2017.07.25 - 2017.10.29	2017.07.24 - 2017.10.28	37369	495	0.92	0.20	0.89	0.20	5.95
228/062	2017.08.02 - 2017.10.05	2017.08.05 - 2017.10.04	23927	0	1.00	0	0	1	N/A
228/063	2017.07.01 - 2017.10.29	2017.06.30 - 2017.10.28	20488	2646	0.91	0.15	0.38	0.72	0.37
228/067	2017.05.22 - 2017.10.21	2017.05.25 - 2017.10.16	37503	1140	0.94	0.23	0.71	0.42	1.67
229/069	2017.04.11 - 2017.09.18	2017.04.12 - 2017.09.15	21958	138	1.00	0.11	0.32	0.77	0.30
230/069	2017.04.26 - 2017.10.27	2017.04.29 - 2017.10.26	40785	96	0.94	0.34	0.98	0.05	26.09
231/062	2017.05.27 - 2017.10.10	2017.05.23 - 2017.10.14	15532	0	1.00	0	1.00	0.00	N/A

232/055	2017.08.06 - 2017.08.22	2017.08.06 - 2017.08.22	30139	0	1.00	0	0	0.00	N/A
232/057	2017.05.18 - 2017.10.17	2017.05.16 - 2017.10.19	17943	2845	0.75	0.90	0.87	0.12	-0.22
232/063	2017.06.19 - 2017.10.17	2017.06.21 - 2017.10.19	35182	0	1.00	0	1.00	0.00	N/A
233/056	2017.08.21 - 2017.10.08	2017.08.24 - 2017.10.11	14673	0	1.00	0.00	0.00	1.00	N/A
233/057	2017.08.13 - 2017.10.16	2017.08.12 - 2017.10.11	28463	1	1.00	1.00	0	0.00	-1.00
233/063	2017.05.25 - 2017.08.29	2017.05.21 - 2017.08.25	53431	12	1.00	1.00	1.00	0.00	0.35
233/067	2017.06.18 - 2017.10.16	2017.06.16 - 2017.10.14	16279	1102	0.87	0.25	0.69	0.44	1.42

[1]Effective validation area- area used for accuracy assessment in each tile after masking for cloud cover and no data areas. [2] Reference burned area – burned area mapped from optical data